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Syntactic Shape Description

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The Chordal Axis Transform (CAT) [1, 2, 3] enables the efficient parsing of shapes into two kinds of semantically significant feature primitives, namely limbs and torsos. We briefly outline here a formal linguistic scheme for encoding shapes in terms of these feature primitives which, when represented symbolically, form the alphabet of the linguistic representation [4]. The linguistic description of a shape consists of a symbolic string representing the sequence of features occurring along the contour of the shape. Further, each character in the string is associated with an attribute vector, which encodes the corresponding feature's metrical attributes, such as length, width, area, etc. Thus, the symbolic string represents the embedding and the structural syntax of the shape, while the attributes capture the metrical aspects of constituent shape features. Limbs and torsos form the generic feature primitives of a shape. Torsos can be further distinguished into two categories, namely *stems* and *handles*. A stem is a torso which, when cut, disconnects the shape into two disjoint components. A handle, on the other hand, leaves the shape connected when cut. It is easy to see that both sides of a stem can be accessed from the outside of the shape while only one side of a handle is accessible from the outside, and that handles occur only in shapes that have at least one hole. Each feature primitive is assigned a vector v of attributes, which may have the length, width, variance, area, etc., of the feature primitive as its components. These components serve to capture the "vital-statistics" of the feature primitive.

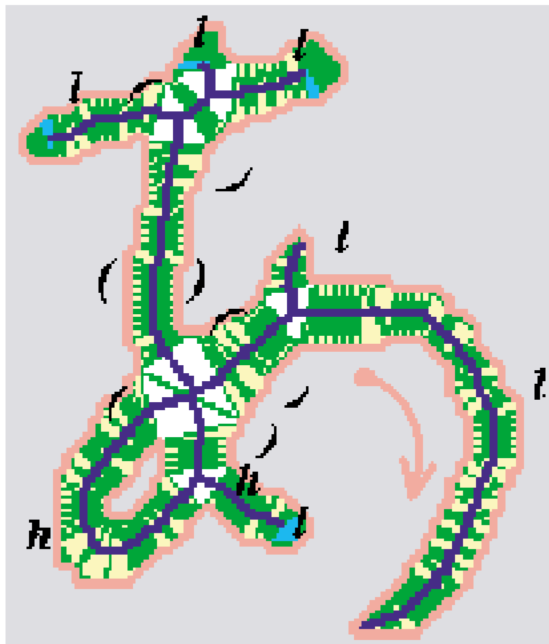

Figure: Japanese letter, hiragana "A." Syntactic labeling of shapefeatures leads to the representing linguistic string: (ll)((ll)l)(hlh);hh.

Tracing (counterclockwise, say,) the outer contour of a polygonized shape which has been decomposed into its feature primitives, we will encounter, in sequence, the feature primitives (i.e., limbs, stems, and handles) of the shape that are adjacent to its outer contour. If we encounter a limb, we will record this by appending the symbol "*l*" to the string (which is initially empty); if we encounter a handle, we will record this by appending the symbol "*h*" to the string. Finally, if we encounter a stem, we will record this by appending the symbol "*(*," if this is the first time this stem has been encountered, or by the symbol "*)*," if this is the second time the stem has been encountered. The resulting string is a sentence in a language that characterizes the exteriors of shapes. The symbols *l, h, (,* and *)* are the alphabets of the language. Each symbol in the string is associated with the attribute vector $v = (\lambda, \omega, \alpha)$ of the corresponding feature, where λ is the normalized length, ω is the normalized average width, and α is the normalized area of the corresponding feature primitive. Thus, we have an attributed syntactic representation of polygonized shape exteriors. Such a representation enables the construction

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of an attributed syntactic-shape database, which serves as a repository of learned shapes to recognize shapes in imagery.

A complete description of a shape with holes is also possible [4] with the above method of syntactic encoding of shapes. This is obtained by encoding each inner hole contour via the feature primitives occurring along it. The shape may then be syntactically represented by a set of strings, each for one hole, and one string for the outer contour. We may choose to represent the shape by a single composite string by concatenating the strings, separated pairwise by a special symbol. For a more detailed description of this work please refer to [4].

As an example, we show in the figure the syntactic labeling of shape features of the Japanese hiragana letter "A." Its representing linguistic string is *(ll)((ll) l)(hlh)* for the outer contour of the shape, and *hh* for its inner (hole) contour, respectively. We have implemented the algorithms for the syntactic shape encoding into ANSI-C code. The geometric and syntactic processing of the example given here requires a few 10-*ms* on a 400-MHz Intel Pentium II PC with a LINUX OS.

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[1] L. Prasad, "Morphological Analysis of Shapes," *CNLS Newsletter*, No. 139, July '97, LALP-97-010-139, Center for Nonlinear Studies, Los Alamos National Laboratory.

[2] L. Prasad, R. Rao, "Morphological Analysis of Shapes," in S*pecial Feature, Supplement to the T-Division Self-Assessment for 1997/1998,* Los Alamos, May 1998, LA-UR-98-1150, p. 107.

[3] L. Prasad, R. L. Rao, "A Geometric Transform for Shape Feature Extraction," Proceedings of SPIE's 45th Annual Meeting, San Diego, CA, Vol. 4117 (2000) 222.

[4] L. Prasad, A. N. Skourikhine, B. R. Schlei, "Feature-based Syntactic and Metric Shape Recognition," Proceedings of SPIE's 45th Annual Meeting, San Diego, CA, Vol. 4117 (2000) 234.

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